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e-BEAM SUSTAINED CO_2 LASER AMPLIFIER

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SUMMARY

The design features of an e-beam sustained CO_2 amplifier are described. The amplifier is designed specifically as a catalyst test-bed to study the performance of room temperature precious metal CO-oxidation catalysts under e-beam sustained operation.

The amplifier has been designed to provide pulse durations of 30 microseconds in a discharge volume of 2 litres. With a gas flow velocity of 2 metres per second, operation at repetition rates of 10Hz is accommodated. The system is designed for sealed-off operation and a catalyst bed is housed in the gas circulation system downstream from the discharge region. CO and oxygen monitors are used for diagnosis of gas composition in the amplifier so that catalyst performance can be monitored in-situ during sealed lifetests.

INTRODUCTION

Over the past two years, a joint RSRE/UK industry programme of work has been underway addressing the design of CO-oxidation catalysts to be used in sealed e-beam sustained CO_2 laser systems.

In order to test catalysts prepared under this contract, GEC Avionics has designed and built a dedicated catalyst test bed consisting of an e-beam sustained CO_2 gain cell, gas re-circulation system and ancillary diagnostic equipment. The specified operating parameters of the test are

Pulse duration	30 microseconds
Discharge volume	2 litres
Repetition frequency	10 Hz
Injected e-beam density	$2mA/cm^2$
Secondary current density	1.5 Ampere/cm^2
Gas flow velocity	2 metres per second
Operating pressure	1 Atmosphere
Gas mixture	1 CO_2:$2N_2$:3He

For a typical operating voltage of 4 kilovolts per centimetre, this results in the following gain cell design requirements:

The gain cell mechanical design is shown in figure 5. The entire construction sits on a central stainless steel plate to which the electron gun is also attached. Channels are provided in this plate to provide coolant to the foil support. Chrome copper was chosen as the foil support material due to its high thermal conductivity combined with good machining properties. The 0.001 inches thick aluminium foil is then trapped between grids machined in the foil support and cathode.

The remainder of the cell is constructed from stainless steel and alumina ceramic (Al_2O_3). A large gas volume is provided to damp out pressure pulses from the main discharge. The ceramic discharge limiters act as flow guides as well as containing the main discharge. Six ceramic assemblies are used - three on each side of the active volume with each assembly being constructed from several piece parts bonded together.

The gain cell PFN consists of nine stages with each stage consisting of a 69μH wire wound inductor and a 50nF Hivolt capacitor. Again, the end stages have a higher inductance to balance mutual inductance effects. At a 40kV charging voltage this gives a total stored energy of 360 Joules. Typical voltage/current characteristics for the gain cell operating with one atmosphere of 3:2:1 $He:N_2:CO_2$ are shown in figure 6. Comparison of the gain cell current with the transmitted primary measurements indicates a current magnification ratio of approximately 3000, in good agreement with measurements reported by RSRE.

As illustrated in figure 1, the gas re-circulation system consists of a motor driven fan, catalyst holder, heat exchanger and connecting ductwork. The fan is a 180mm diameter, 74mm wide centrifugal impeller capable of maintaining a pressure drop of up to 100mm of water at 60 litres per second flow rate.

The fan may be coupled to the drive motor by either a magnetic or ferrofluidic coupling.

The catalyst holder comprises a section of ductwork with a 5½ inch internal bore fluted at either end to match the rest of the ductwork, this diameter being dictated by the maximum size of commercially available ceramic monoliths. The catalyst sample is held in place using spring loaded retainers with a maximum sample length of 12 inches being accommodated. Sections of ductwork either side of the catalyst holder contain diagnostic ports to allow gas temperature and flow rate measurements to be made as well as being CO and oxygen monitoring points.

The heat exchanger is a chlorodifluoromethane cooled unit with a capacity of 4kW. As the response time of this type of cooler is long, temperature control is achieved by heaters placed in the ductwork before the heat exchanger. The temperature control circuit then maintains the gas temperature by altering the heating rate rather than the cooling rate.

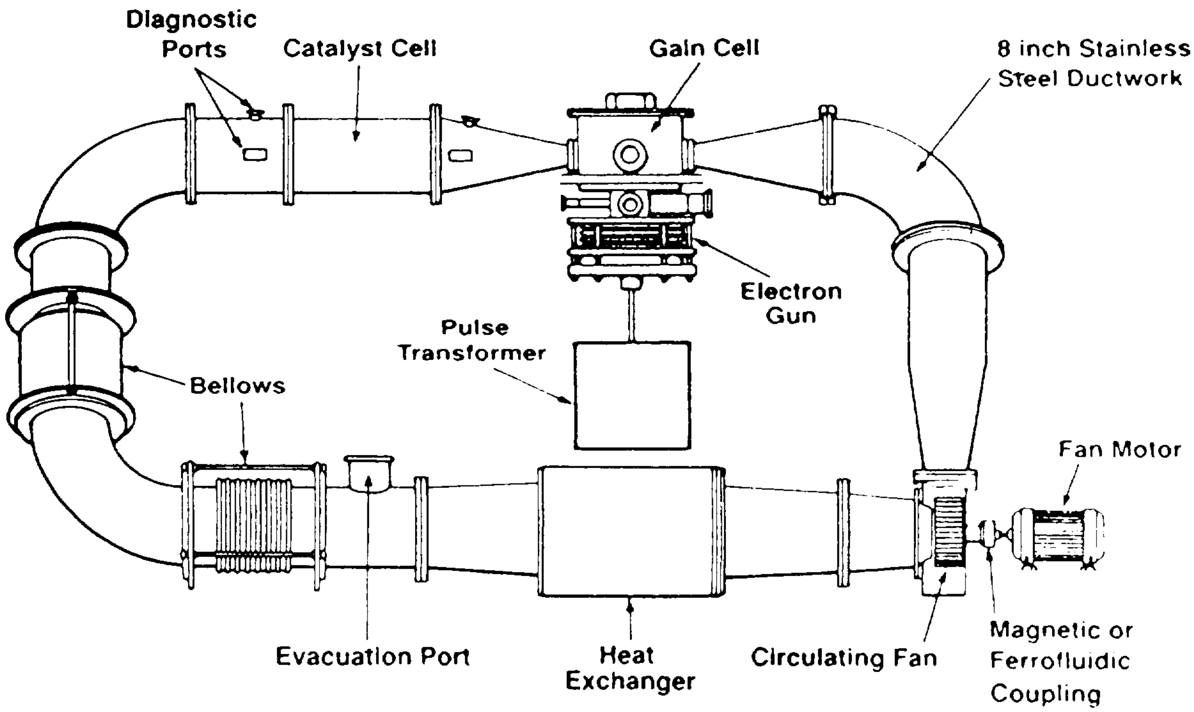


FIGURE 1: TEST BED SCHEMATIC

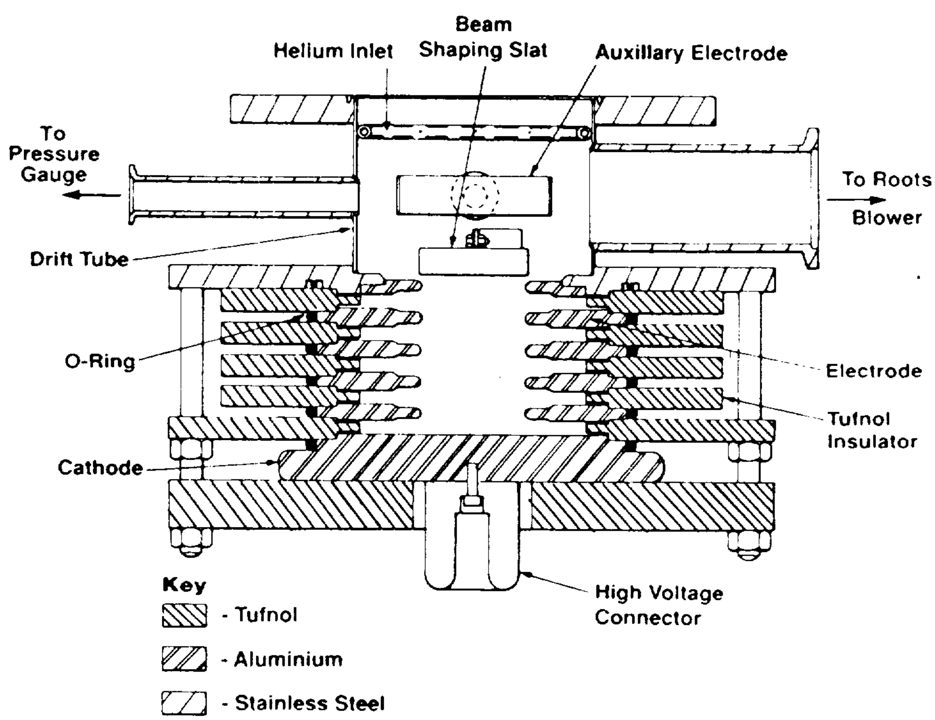


FIGURE 2: ELECTRON GUN DESIGN

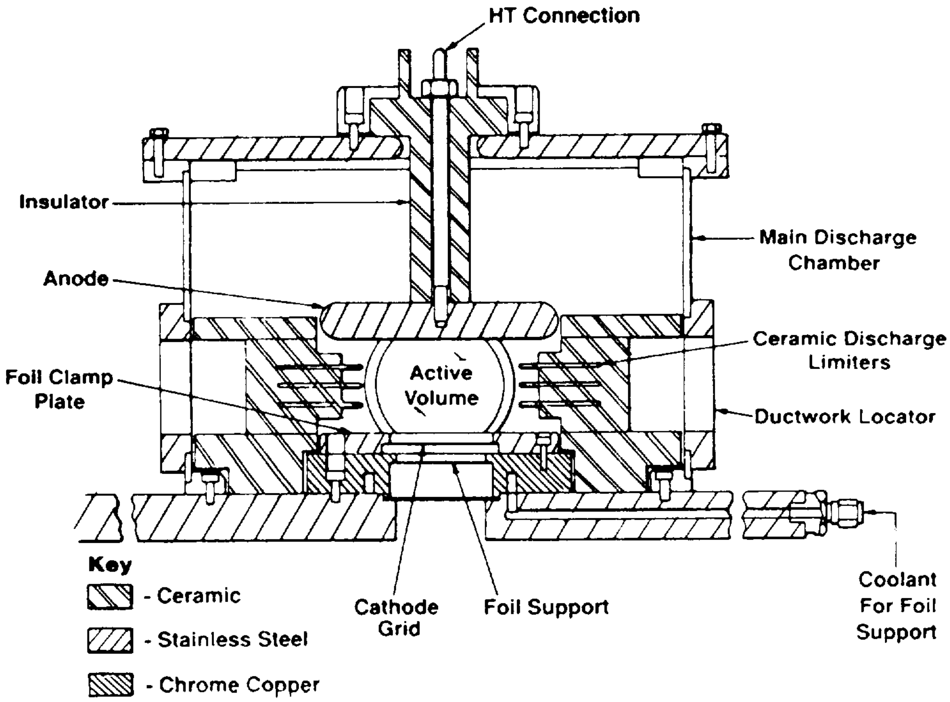


FIGURE 5: GAIN CELL DESIGN

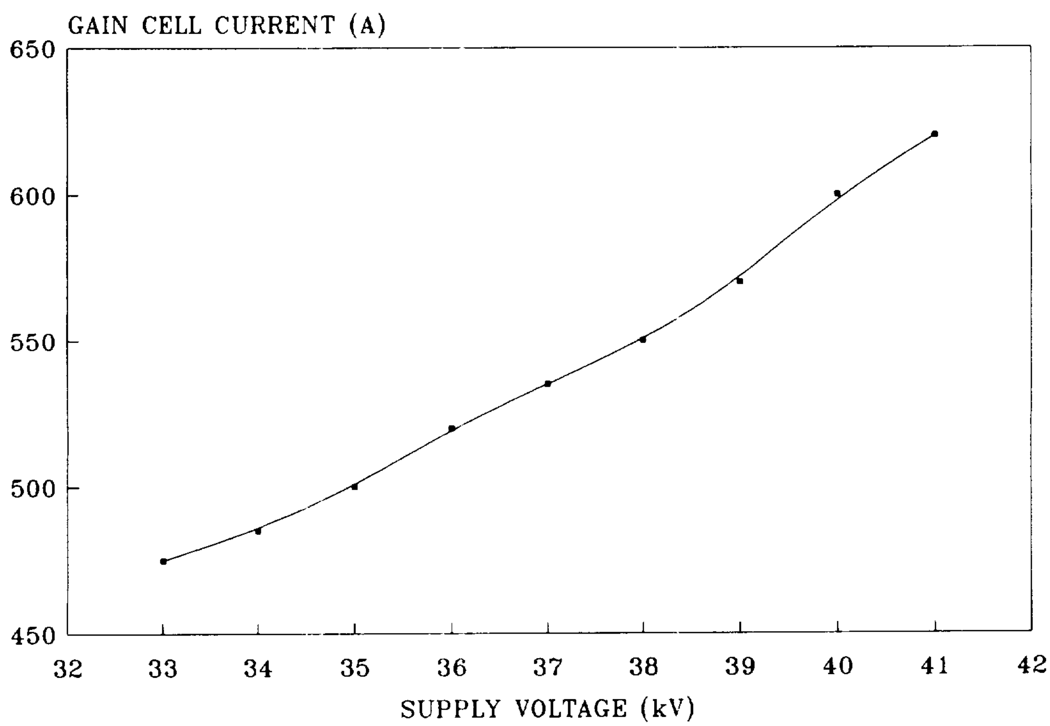
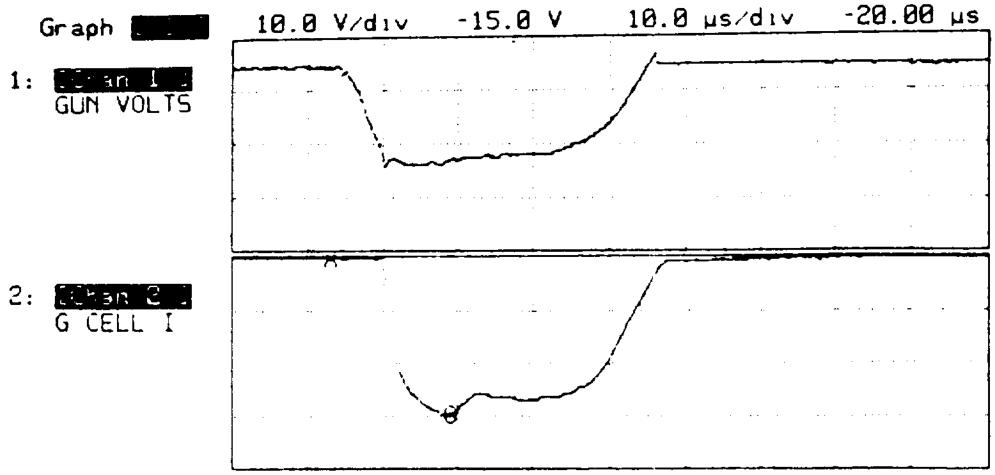
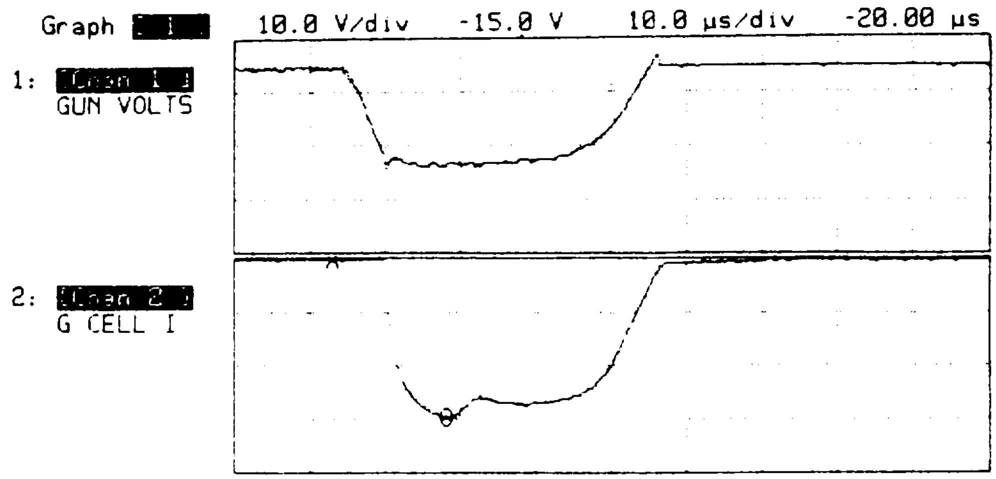


FIGURE 6: GAIN CELL CHARACTERISTICS



WAVEFORMS AT BEGINNING OF LIFETEST



WAVEFORMS AFTER 2 MILLION PULSES

FIGURE 8